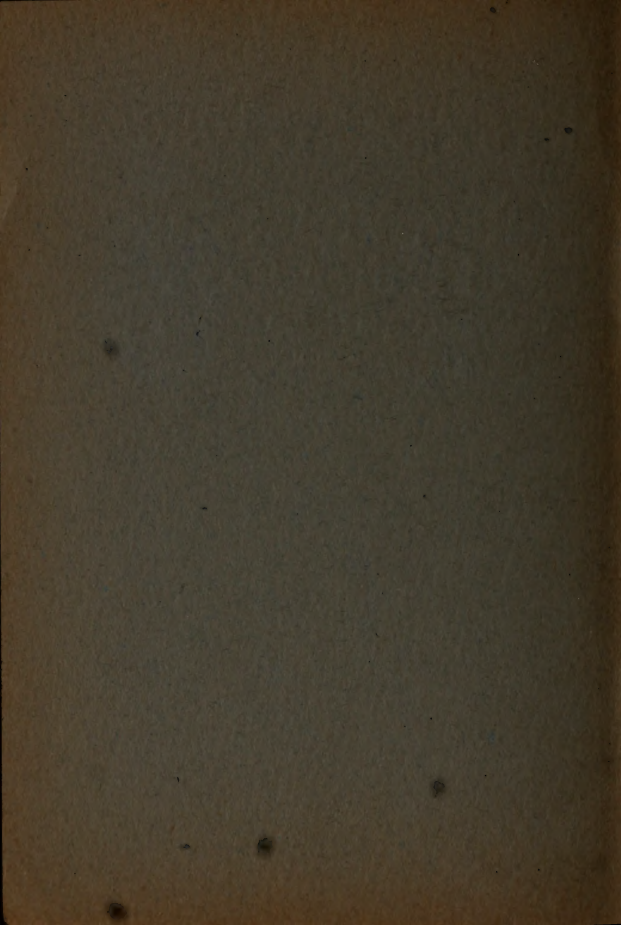


LITTLE BLUE BOOK NO. 1050
Edited by E. Haldeman-Julius

X-Ray, Violet Ray and Other Rays

With Their Use in Modern Medicine

Maynard Shipley



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HALDEMAN-JULIUS COMPANY
GIRARD, KANSAS

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PRINTED IN THE UNITED STATES OF AMERICA

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INTRODUCTION

Highly important as are the phenomena of Radioactivity from the physical, chemical, medical, and philosophic points of view, they are hardly comparable in their relations to the affairs of our everyday life to the Roentgen or X-rays, and to the invisible violet or ultra-violet rays. The X-rays are utilized today in hundreds of practical ways, and are vastly important also in surgery, medicine, dentistry, and in biological investigations. It is perhaps not too much to say that the discovery of the so-called X-rays should be numbered among the two or three most important revelations of modern science. This will be clearly demonstrated in the course of the chapters to follow.

X-RAY, VIOLET RAY AND OTHER RAYS

CHAPTER I

EVERYDAY USES OF X-RAYS

To enumerate and describe all the practical uses of X-rays, apart from medicine and scientific research in general, would require a good many more pages than can be devoted to the subject here. To take a few cases at random, without describing the instruments and methods employed: radiography reveals flaws in the structure of iron and steel building and bridge materials, and in the cylinders of airplane engines, and so avoids accidents. In England a gasoline or petrol tank was shown to have rivet heads on the outside and none on the inside.

Serious defects in the steel axles of railway and automobile "under carriages" have been discovered by radiography. In one case, at least, the axles had been drilled in the wrong position and the holes had been simply filled with metal and covered over. An entire lot was rejected in consequence and probably serious accidents were forestalled.

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“Cracks in castings, bad welds and weak places which do not show on the surface of metal are perfectly clear to the searching rays. How much would you give to *know* that that welded part in your automobile is really solid and perfect, that it contains no flaw to break down some day when you are twenty miles from a machine shop? A well-known mechanical engineer said recently that in ten years a metallurgical X-ray machine will be as vital a part of the equipment in an automobile repair shop, a foundry, or machine shop as it is now in a dentist’s office.”

We are assured by *The Iron Trade* (73:26) that “the practice of analyzing metals by means of X-rays is only in its infancy. There is every reason to believe that soon great advances will be made in determining the crystallization and therefore the properties of metals. Students of metallurgy are well aware that the properties of metals and other bodies depend on the nature of their crystallization. The microscope has rendered valuable service largely because it enables the form and arrangement of the crystalline grains to be studied. The X-ray carries the same form of inquiry into a region 10,000 times more minute, thereby furnishing new evidence as to crystalline structures, so that it is

now possible to see the atoms and the molecules, and the way they form crystals. Every crystal has its characteristic X-ray spectrum and can be identified thereby even when the individual crystals are beyond the resolving power of the microscope and the substance is in danger of being called amorphous. If a specimen contains a mixture of crystalline substances, the spectrum shows the combined effect of all the substances, and provided each individual spectrum is known, the specimen can be analyzed."

The X-rays are also used to determine the quality of the fabric in automobile tires, and even to detect irregularities in the centers of golf balls, and to reveal why some of them fly straighter and farther than others.

"The professional detective, too," says Mr. Wilfred S. Ogden (*Popular Science Monthly*, August, 1923), "will find X-rays useful in his business. Consider the detection of infernal machines, for example. Two or three X-ray plates will tell an investigator just what is in a suspicious-looking box. If it is a bomb the X-ray will show him how to get it apart and render it harmless. Immediate detection of false bottoms in trunks is child's play with the X-ray. When the government provided its

customs inspectors with X-ray machines the gems which smugglers try to hide in the linings of clothes or in hollow-handled hair-brushes might as well be worn openly.

“The X-rays give us one of the easiest ways to detect the alteration of checks and other documents. It is seldom that such an alteration is made with exactly the same ink used on the original. Inks even of the same color, differ in the way they affect the rays. In most cases all that is necessary to detect an alteration is to place the suspected document for a moment under the X-rays and make a photograph of it. The new ink used in the alteration will stand out clearly as different from the old.

“The industrial detective will find X-rays just as useful. The adulteration of foods by sawdust, sand or clay; the adding of too much filler to paper; the presence of grit in lubricating oil, all will be revealed.

“Another use of the rays comes home to every cook and housewife. X-rays constitute the only sure way to tell good eggs from bad. Pass each egg in turn through the X-rays and let its shadow fall on a chemical screen. You will see exactly what is inside each egg. The

ones containing hopeful chicks may be rejected."

One of the most remarkable economic or biological uses of the X-ray so far developed is the study of silk-worms and their diseases. The Silk Association of America has established a laboratory—Department of Sericulture—in the Canton Christian College, presided over by a staff of Chinese and foreign entomologists. Here the silk-worm is X-rayed by powerful microscopes, and all his disorders diagnosed and corrected, says Mr. Philip A. Yountz (*Scientific American*, September, 1925).

"Numerous autopsies on deceased members of the silk-worm tribe revealed that from 50 to 100 percent of the worms raised in South China were infected with diseases that made the infant mortality rate excessively high and destroyed the value of the silk from those hardy enough to survive. The elimination of these diseases would enable South China to produce four or five times as much silk."

In Great Britain, X-rays are used in the analysis of coal, the method being an adaptation of the X-ray stereoscope.

In Berlin, S. Nalken, a noted criminologist, has devised an important improvement in finger-print identification. X-ray pictures are ob-

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tained of the finger, with the muscles and bones. This is done without the use of any chemicals that could obstruct the delicate furrows of the finger lines. Moreover, the finger bone is shaped so characteristically as to aid identification. Whenever a certain likeness of finger-lines is discovered, the bones are examined to see if further research is necessary.

Picture fakers have been dethroned by application of the X-ray to paintings. Recently painted "old masters" are now easily detected. Modern artists use white-lead, which is more opaque than the "priming" or "sizing" used by the older artists; and the X-ray device "made in Germany" in 1914 by Dr. Faber, and further developed by the French expert, Dr. André Chéron, at once distinguishes the old from the new. One picture by Van Ostade, of men drinking at a table, proved to be a fraud when submitted to the X-ray; it had been painted over a study of dead birds. Another, called "The Royal Child," a supposed 16th century work, now in the Louvre, was proved to have been painted during the 19th century over a picture of very much earlier date.

During a popular lecture on the X-ray in London, before the Royal Institution, the distinguished physicist, Prof. G. W. C. Kaye,

showed a number of radiograph slides, among which were two pictures by Dutch painters, one representing the Madonna and the other the Crucifixion. In the former, the Madonna appeared to be looking at something which was non-existent in the canvas, and a radiograph proved the missing object was a child which some former owner of the picture had painted out. In the second picture, a woman in the attitude of prayer was found to have been painted over what was in the original the figure of a man in monk's garb.

The first X-ray pictures ever taken of a mummy were completed by scientists at the American Museum of Natural History, New York City. The pictures showing the skeleton in detail are expected to be a great aid in studying the development of bone formations in the evolution of man. This first subject of the scientists' X-ray was a South American Indian mummy. Fake mummies, like false gems, are instantly detected by X-ray methods.

One of the methods used for detecting the theft of diamonds at the mines is to examine the workmen with X-rays. Of course, a fluoroscope is used to make the X-ray image visible, and this is the type used in any regular X-ray work.

The X-rays are now being used in shoe-stores—"foot-o-scope" instruments—to enable shoe salesmen to see the bones of a customer's foot and thus make correct fittings of shoes.

A few years ago there arrived from Germany a new kind of mechanical doll. "A secret mechanism inside enabled it to walk, sit down or stand up, and to do other unusual things. The importer in possession of the sample doll would not allow it to be opened. But one of the competitors borrowed the doll. He had promised not to open it. But he made some X-ray photographs of it. Now he is manufacturing these dolls himself."

During the World War every effort was made to introduce contraband materials into Germany and if it had not been for the all-seeing eye of the Roentgen ray, it would have been impossible to prevent materials of the utmost importance to the enemy from reaching him by way of neutral countries. Efforts were made repeatedly to smuggle rubber and copper by burying them in bales or bundles of other materials. It would have been impossible to have made a minute investigation of every bale that was shipped, but by means of X-rays it was possible to see through these bundles and packages and locate any substances that were more or less opaque to the rays.

The X-ray has been found useful for examining timber up to 18 inches thick for internal knots, resin pockets, cracks and other defects.

"When submarines were active and the supply of the best kinds of wood was uncertain, it was necessary to make some of the wooden parts out of small pieces of ordinary wood fitted and glued together. The way these pieces were joined and fastened was extremely important. A bit of weak glue inside some little strut might mean a disastrous collapse in the air. But real inspection seemed impossible, for the places where important faults might exist were hidden from view. Finally scientists solved the problem by building an X-ray apparatus with which they could look into the inside of each built-up airplane part and tell whether it held some little imperfection which might prove dangerous.

"This 'internal inspection' of wooden articles by X-ray has been applied, since the war, to many other articles. Hidden joints inside high-class furniture and cabinet work, invisible knots and flaws inside the wood itself, can be determined easily by X-ray examination." (W. S. Ogden).

The Scientific American (September, 1924) published an abstract of a paper read before

the *Deutschen Bunsen-Gesellschaft*, in which Dr. D. Coster showed that "the relations between the X-ray spectra of the different elements are so simple that, in some respects, they are more useful for purposes of chemical analysis than ordinary luminous spectra. An important advantage is the fact that the X-ray spectrum of an element is quite independent of the nature of the compound containing it. It is easy to detect the presence in a mixture of which not more than one milligram is available. Certain precautions are necessary in examining the X-ray spectra; although the number of lines for each element is comparatively limited, recent observations have shown the existence of a number of weaker lines; in addition to this, with the high voltages now generally used, not only the spectrum of the first order, but also those of higher orders appear. Slight impurities in the material of the anticathode, and in the subject under examination, also give their lines, so that there are often various possibilities to be considered before a given line can be explained. Not only the wave length, but also the typical appearance of the suspected lines must be considered, as well as their relative intensity. By measuring photometrically the intensity of the spectral lines it is possible, in some cases, to obtain

a quantitative estimate of the amount of an element present in a mixture."

Another method of rapid analysis of material in the laboratory by the use of X-rays in a much shorter time than that required by the older chemical methods is that devised by Professor Urbain, of the Minero-Chemical Laboratory at the Sorbonne, with the assistance of Eugene Delaunay. Mr. Delaunay, who did the actual work of testing the new X-ray method, says there is no risk of error.

By employment of X-rays the scientist is now able to ascertain the arrangement of the atoms and molecules within the crystal "network" (structure—or "space lattice" of the crystal).¹ The results are obtained from the study of the reflection and refraction of the rays by the crystals, or, more precisely, the successive rows of molecules in the crystal. These act toward the extremely short X-rays in the same way as a grating spectroscope does to ordinary light-rays.

Man's ability to lengthen the ultra-violet end of the spectrum is limited by his capacity to

¹This phase of our subject can only be alluded to in this little book. For an authoritative yet easily understood exposition of the subject, see Bragg, W. H. and W. L., "X-Rays and Crystal Structure"; also Kaye, G. W. C., "X-Rays"; and, for more advanced reading, deBroglie, Maurice, "X-Rays".

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provide a diffraction grating, or a mineral prism, which can split up light-waves of increasingly greater frequency (or shortness). The width of a grating space (a fine line on speculum metal, which acts as a minute mirror) must be comparable to the wave length of the light. Previous to the discoveries of Prof. Max von Laue in Munich (now in Zurich), and Prof. William Henry Bragg, of the University of London, no grating or other material was known whose spaces were as small as the wave length of X-rays. Laue conceived the brilliant idea that the regular arrangement of the atoms in a crystal might serve the purpose. They did. Bragg, and later his son, Prof. W. L. Bragg, of the University of Manchester, followed up the work of Laue with results of immeasurable value to science.

A very important relation between the atomic number of an element and its X-ray spectrum was discovered by the brilliant young English physicist, H. G. T. Moseley (1888-1915), in his 26th year, a year before his death by a Turkish bullet at the Dardanelles. While analyzing the characteristic X-rays which are given off when any kind of substance is bombarded with cathode rays, Moseley found that the atoms of all the different substances emit radiations or

groups of radiations which are extraordinarily similar, but which differ in their wave lengths as we proceed from substance to substance; the frequencies (wave lengths) change by definite steps as one progresses from elements of lower to elements of higher atomic weights. Through Moseley's epoch-making discovery we now know that each of the 92 elements, from hydrogen to uranium, is built up by successive additions of one positive charge (proton) and one negative electron, and that the atomic numbers—from 1 to 92—correspond to the number of protons and electrons in each successively heavier (and more complex) atom.

CHAPTER II

CURATIVE VALUE OF X-RAYS

In my Little Blue Book on Radium (No. 1000), it is shown that the "emanation" and the "gamma rays" of radioactive substances are being used to great advantage in our hospitals; but that certain dangers to the patient's normal cells attended employment of these radiations.

It is gratifying to note that successful X-ray treatments are now being given in cases of cancer, rays being produced—under high-tension currents—that are almost identical with the gamma rays of radium.

Moreover, the X-rays have a double value in medicine. In the first place, they are used as an aid to diagnosis, forming those branches of radiotherapy known as radioscopy and radiography. Then they are also used to great advantage in the alleviation or cure of certain maladies. By means of radioscopy or radiographic examination it may be found that there is a tumor in the chest, and as a result of that diagnosis it may be decided to institute treat-

ment (radiotherapy) by means of X-rays or radium rays or the two combined.

The method of employing extremely penetrating X-rays—under high voltage and amperage—seems to have been first used in Germany, during the World War, but was soon developed to a high degree of efficiency in France, England and the United States, especially by Dr. William Duane, professor of biophysics at Harvard.

As early as 1919, Professor Dessauer, in Germany, produced the penetrating X-rays by means of a high-tension current ranging from 170,000 to 240,000 volts. It was later found that rays at 200,000 volts became homogeneous, so that a further increase was considered as of no therapeutic value.

In March, 1923, Dr. I Seth Hirsh, head of the X-ray department of the Bellevue Hospital in New York, gave a drastic treatment—for cancer—of four periods of 16 hours each with the X-rays at 250,000 volts, apparently with satisfactory results. The patient suffered no pain or inconvenience during the treatment with the exception of occasional nausea. A year later an experiment was made in a Philadelphia laboratory where an X-ray treatment of 300,000 volts was used. It seems that allevia-

tion rather than cure has been the result of nearly all cases where cancer had been well advanced.

Other important improvements, meanwhile, were being introduced by the German specialists, during the World War and later, among which was the just mentioned method of giving large tissue-destroying doses, requiring from ten to 15 hours; to this was added careful filtration of the rays, and the invention of the *ionto*—a quantimeter for exact measurements. A number of malignant diseases is reported to have yielded to this new system of massive doses under higher voltage. But Professor Duane has stated that neither X-rays nor the gamma rays of radium should be considered as a permanent cure for cancer.

Until recently the tubes in which X-rays are produced have always been made of glass. The latest discovery is a tube made of fused silica, or vitreosil. Vitreosil permits the passage of the short rays, will stand a much higher temperature than glass, and is much stronger. This means more continuous service from X-rays.

According to Dr. Francis C. Wood, director of the Crocker Institute of Cancer Research of Columbia University, a marked advance in the

treatment of cancer has been made possible by a new type of X-ray tube, the invention of Dr. C. T. Ulrey, of the Westinghouse Company. The new tube has a higher emissive power—in other words, it is as if the candle-power of an ordinary lamp were increased six-fold. It is besides designed for use with higher voltages than have previously been practical in Roentgenology. The result is to reduce the necessary exposure from two or three hours per patient to 20 minutes, and to increase the life of the tubes. Incidentally, the new tube gives a greater proportion of the type of rays that cure certain forms of cancer, and less of the sort that attack healthy tissue.

A revolutionary discovery by Dr. Jacques Forestier, of Aix-les-Bains, France, for which a gold medal was awarded him in 1925 by the French Academy, has made possible a method of exact diagnosis by X-rays heretofore deemed by many workers impossible of attainment.

As is well known, it is not difficult to make an X-ray picture of the bones of the body. They are so much denser than the soft parts of the body that, even with the ordinary photographic plate, it has been possible to photograph them fairly well. By pumping the stomach full of gas or air—which are highly transparent to the

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X-rays—and then applying the X-ray, it has sometimes been possible to locate the beginnings of cancer of the stomach, and the place of malignant growth.

Another method in common use is to give the patient about a pint of some substance opaque to X-rays, such as bismuth carbonate, thus making it possible to record the passage of the mixture, the outline of the stomach and the intestines thus being made visible. In this way ulcers of the stomach have been frequently located.

Bismuth and similar substances could not be injected into the brain or spinal cord, on account of their poisonous effect on the highly sensitive cells of these regions. Now, thanks to the method discovered by Dr. Forestier, the cavities of the brain and spine can be safely explored, as well as the network of bronchial tubes in the lung—the so-called “bronchial tree.”

In an interview with Mr. David Dietz, Dr. Forestier said (in part):

“I make use of a French oil called lipiodol. It is a chemical compound composed of poppy-seed oil and iodine. The chemical previously had been used as a treatment for certain dis-

eases, such as goiter. But no one had ever thought of using it in X-ray work.

"I noticed that where patients had been treated with lipiodol opaque spots appeared when X-ray pictures were made of the treated parts. It occurred to me, therefore, that lipiodol could be used as a means of making photographs.

"Accordingly, in company with Dr. Sicard of Paris, I began to experiment. We worked with animals until we were convinced of the correctness of our method. When we were sure that it was safe we tried it on human beings. I have used it in more than 5,000 cases in Europe without having a single adverse result.

"The lipiodol is injected into the brain cavity or the canal of the spinal cord or the bronchial tubes and then a regular X-ray photograph is made. The oil renders the injected part opaque to X-rays and they show up as sharp black images in the photographs.

The method is of particular value when a patient is suffering from paralysis which has been caused by a pressure of a tumor or growth somewhere along the spinal cord. In this case a drop of the oil is injected into the spinal canal at the base of the brain. In a healthy

patient it would immediately travel to the base of the spine. But in the paralyzed patient it only travels as far as the point of compression. The X-ray picture therefore reveals the drop of oil as a black spot. The surgeon then knows the exact spot at which to operate in order to find the growth causing the pressure, which in turn results in paralysis.

"In diagnosing the lungs with the use of lipiodol the injection in the bronchial tree enables the X-ray worker to tell at once whether the patient is suffering from diseases of the bronchial tubes themselves, or from diseases of the lung tissue, such as tuberculosis."

It is gratifying to be able to relate that along with the improvements already described, progress has also been made in the preparation of photographic plates required by the radiographer. Until recently no photographic plate had been made which fully met the requirements of X-ray work, and there was little contrast in X-ray photographs. They were all much too sensitive to the longer (visible) wave lengths, and produced blurring effects.

Early in 1921 an excellent photographic plate, 25 times more rapid than anything previously known, was invented by Dr. Leonard A. Levey, a prominent member of the Roentgen Society. It makes an X-ray photograph of the vital or-

gans of the living body whose movements have hitherto blurred the images on the ordinary photographic plate. Distinct pictures of the heart, lungs and stomach can now be made. Dr. Levey has made snapshot photographs of the heart, lungs and kidneys. All were taken in a flash with the X-rays on the new plate.

Dr. H. Becher has called the attention of Americans to the achievement of Dr. Schleusner, an eminent German authority in photochemical matters, who has succeeded, after years of investigation, in sensitizing photographic plates for X-ray use by an addition of certain organic salts which are absorbed by the grains of silver bromide on the photographic plate. The plate thus formed is very responsive to the soft rays of an X-ray tube. The soft rays are relatively longer than the hard Roentgen rays. One could compare the soft rays to blue-violet light, if their effects on this new photographic plate are used for the comparison. Photographs taken with such plates give very contrasting effects.

On the "Neo-Roentgen plate" the effect of the yellow light was almost nil. For this reason, developing the plate is considerably facilitated, as the plate can be exposed to yellow light and the attendant, who need not be a skilled oper-

ator, can examine the plate in a rather brilliant light without necessarily guessing at possible results. The examination of the plate under a ruby light is, therefore, completely done away with. It follows that if the new X-ray plate should come into general use, much clearer X-ray photographs would be possible; the time of exposure could be decreased; an unskilled operator could develop the plate in a room flooded with yellow light. Such improved plates are now being extensively used.

While not attempting to enumerate all the special affections to which X-ray therapy is now being successfully applied, a few uses may be mentioned.

X-RAYS CURE WHOOPING COUGH

In a preliminary report published in the *Medical and Surgical Journal* (Boston), Dr. Henry I. Bowditch and Dr. Ralph D. Leonard express the belief that a valuable cure for whooping cough has been found in X-ray treatment of this disease, which has stubbornly resisted most, if not all, of the other remedies applied.

Definite improvement was noted in most of 26 cases of active pertussis (whooping cough) treated with the X-ray, the subjects of which ranged in age from three months to 40 years,

with disease stages from one to ten weeks. The physicians added that they could not give any rational explanation of the action through which the X-ray appeared to produce beneficial results. The report said:

"Each patient received three or four applications of the X-ray at intervals of two or three days."

Many of these cases have not been observed sufficiently long to determine the final result. Nevertheless, "it is evident to us that there resulted a definite improvement in these patients which cannot be explained by mere accident. . . . It does not seem likely that [the beneficial result] is due to any direct bactericidal property of the X-ray.

"We feel warranted in classifying a small percentage of these 26 cases under the heading of "prompt cures." By this we mean that after two or three applications of X-rays, covering a period of six days, the spasms and whoops entirely disappeared and the patients were clinically well, except for, possibly, a very slight cough.

"The bulk of the cases, however, we have classified as relieved. This group consists of perhaps 70 percent of the total. By relieved we mean that there has been a gradual diminution in the number of spasms.

"There is a small percentage of cases, perhaps 10 to 15 percent, which apparently were not relieved. In this group are included one moribund case and one rather difficult feeding case.

"While our evidence so far is not sufficient to warrant any definite conclusions, we have the feeling that the X-ray at the present time may be of more value in the treatment of pertussis than any other form of treatment, including serum."

X-RAYS FOR MALARIA

An Italian physician, Dr. Antonio Pais, of Venice, has since 1916 been successfully treating malaria by means of X-rays. This treatment is, however, not employed as a substitute for quinine, but merely to reinforce its action. The X-rays are directed toward the region of the spleen, and the effect is to reduce its enlargement. At the same time the composition of the blood is modified. The success obtained by Dr. Pais has, according to the *Bibliothèque Universelle et Revue Suisse* (Lausanne), been so great that the Italian Government decided to introduce his method of treatment into the military hospitals.

Since the war the treatment has been studied by Prof. B. Grassi, who made a report, at an

Italian scientific meeting, in which he declared the action of X-rays upon chronic malaria to be "truly marvelous." The *Bibliothèque Universelle* says, regarding earlier treatments:

"The attempt was made by them to destroy the parasite contained in the spleen. But it is now known that the X-rays employed for therapeutic action have no effect upon micro-organisms, although they may be injurious to the elements of the blood. In the method devised by Dr. Pais, the X-rays are employed to stimulate the functioning of the spleen, of the marrow, and of the lymphatic elements by means of slight but prolonged excitation; they are employed in infinitesimal doses—homeopathically, so to speak. Thus the result is absolutely different as well as the method."

Dr. James B. Murphy demonstrated that accompanying cancer grafts on immune animals there occurs a general increase in the circulating lymphocytes and hyperplasia of the lymphoid tissue. When the lymphoid tissue of immune animals was destroyed, the immunibility was annulled. Two methods of increasing the lymphocytes have been found, namely, diffuse small doses of X-rays, and dry heat. Mice with lymphocytosis induced by these agents show increased resistance to replants of their own tumors. The results afford ground for hope of

human application. (Reported in *Scientific American Monthly*, January, 1920, page 96.)

It has been found that actively growing tissue, whether normal or pathological, is the most susceptible to X-rays, and it is comparatively easy to sterilize a number of species of animals without otherwise injuring them. (Prof. James W. Mayor, *Science*, September 23, 1921.) C. R. Bardeen found that X-rays prevent worms from regenerating lost parts. Observations of the effect of exposure to X-rays on the fertility of animals were described in a paper by Prof. L. H. Snyder of the North Carolina College of Agriculture. Exposure of male rats to X-rays, he said, had rendered them sterile at the end of two months, the animals regaining fertility when no longer subjected to the rays.

If not handled with due caution and skill, X-rays may do more harm than good, provoking malignant growths as well as retarding their development. As early as 1911, Otto Heese published a record of 54 cases of cancer caused by means of improper handling of these powerful rays.

In the early days of X-ray therapy the nature and effects of these radiations were wholly unknown. Operators did not hesitate to test

and adjust their tubes by throwing the shadow of their hands on the flouroscope. X-rays do not make objects visible to the human eye, and to see the effects of them it is necessary to interpose a special screen between the eyes and object through which the X-rays are to penetrate. The cardboard screen is coated with a fluorescent substance, such as barium-platinum-cyanide, or calcium tungstate. This screen is best placed in one end of a black wooden or pasteboard box, against the other end of which the eyes are placed when in use.

This screen under the influence of X-rays becomes luminous and enables one to see shadows or silhouettes of objects of denser material interposed between the eyes and the X-ray tube, when the tube is in operation.

CHAPTER III

MARTYRS TO RADIOLOGY

It was not until several years after the discovery of X-rays by Roentgen, in December, 1895—after operators had been severely burned in laboratories and hospitals all over the world, and surgeons and physicians began to compare notes, that the pathological effects of X-rays were discovered and understood.

Says John Macy (in his memorial volume on Walter James Dodd, heroic victim of 50 separate operations due to X-ray burn):

“It is easy now to understand what was happening to Dodd and his contemporaries. In a modern X-ray machine the strength of the current, the quality of the spark, all the conditions, are determined by metrical instruments. In the early days the operator tested his tube and adjusted it by throwing the shadow of his hand on the fluoroscope; by the look of the shadow he judged how the machine was behaving. First he used the left hand until that became too sore, then the right. And until devices were found to focus and confine the rays, the face of the operator was exposed, and sometimes the neck and chest were burned. A limited exposure to the X-ray is as

harmless as a walk in the sunlight. It is the repeated, continuous bombardment of the ray that is calamitous. Dodd and the other pioneers lived in the X-ray."

John L. Bauer was the first victim of the X-ray, in 1906. He was followed in 1914 by Henry Green, who, although he knew he was doomed, and in spite of the fact that he had become almost helpless physically because so much flesh had been cut away in amputating cancerous growths, persisted in his work to the end.

Major Eugene Wilson Caldwell of the Medical Reserve Corps of the United States Army, the inventor of the Caldwell liquid interrupter and other devices for therapeutic use, lost his life in 1918. Dr. Charles Infroit of the Salpêtrière Hospital, Paris, died on November 29, 1920. One of Dr. Infroit's hands became infected in 1898 as a result of his continuous use of the X-ray, and an operation was performed. After that he had 24 other operations, 22 of them performed in the last ten years of his life, the last on August 1, 1920, when his right arm and left wrist were amputated.

Dr. Charles Vaillant, whose heroic services to humanity have made necessary 13 amputations until now he is armless, on February 19,

1923, received from United States Ambassador Herrick the Carnegie plaque, while the cravat of the Paris Gold Medal of the French Legion of Honor was conferred upon the martyr. Physicians say further amputations are inevitable, and that these will result in Vailant's death.

In 1921, the eminent English radiologists, Dr. Cecil Lyster and Dr. Ironside Bruce, and Dr. Adolphe Leroy of the St. Antonie Hospital in Paris, died martyrs to their noble profession. "All of these men went knowingly to death. Perhaps they did not take their sacrifices in the spirit of the saint, possessed by a vision of suffering humanity. Theirs may have been the ardor of the scientist, the endurance of a worker who hears the challenge of nature's silence and goes to battle. But in themselves they express the powerful urge of a spirit that longs to see, to feel, to know, and to possess all the mysteries of the universe. It is the same spirit that makes men rebel and agonize for a better order of humanity. These men seem better than the world that produces them. But each of them, when he dies, may pull the rest of humanity a little closer to his level."

Dr. Frederick Henry Baetjer of Johns Hopkins Hospital has only two of his ten fingers left.

He lost the other eight as the result of burns received in X-ray experimentation.

Dr. Francis Carter Wood, X-Ray and radium expert of the Crocker Special Fund Cancer Laboratory of New York, calls particular attention to the fact that "the deaths which are occurring now are the results of repeated exposures ten or more years ago, when no one knew what the effect of the rays might be. The burns suffered then were the result of continuous exposure without protection against the rays. One exposure, or a moderate number of them, would do no harm; but before the present perfection of the apparatus it was necessary to adjust the focus for each picture, and the operator would do this by looking at his bare hands through the fluoroscope. This resulted in chronic burns, and the burned flesh formed a fertile soil for cancer. Lead one-quarter of an inch thick will stop both radium and X-rays."

In Dr. Wood's opinion, workers in X-rays today "need not suffer any ill effects except through their own carelessness."

A discovery which promises to put an end to the dangers to life and limb risked by those who engage in working with X-rays was communicated to the Academy of Sciences of Paris

as early as May, 1920. It is the result of experiments by Dr. Pesch of the Faculty of Montpellier, who himself is one of the sufferers from X-rays, and who has long been seeking the means of protecting his young confrères.

He found that deep red rays are antagonistic to the ultra-violet rays which produce irritation and burning of the skin, and certain oxidations. Thus, by the simultaneous application of both rays he secures immunity for X-ray workers. He has already proved that erythema can be prevented by the application of red rays. Daniel Berthelot, who announced the discovery to the Academy, recalled that as long ago as 1872 the antagonism of extreme rays of the spectrum had been foreseen by Becquerel in his study of phosphorescence.

Dr. Pesch employs a filter composed of a plastic material that allows only the red and yellow rays to pass. It is claimed that by means of this filter not only are the X-rays made harmless, but its employment effects a cure for radio-dermatitis, the affection which has maimed or killed so many of the early workers in X-ray therapy.

According to Dr. G. Contremoulins, Chief of the principal laboratory of the Paris hospitals, whose researches and experiments were begun

in February, 1896, the usual methods of protection even today are not always adequate. Says he (in *La Démocratie Nouvelle*, Paris, April, 1921):

“Young radiologists, especially those born of the war, take no heed of the experience acquired by their elders, being quite convinced that the glasses, gloves and aprons containing lead offer a perfect protection—they even imagine that strictly speaking they might get along without them.

“Like a child which hides behind a wooden door to shield itself from the bullets of a machine gun, our young radiologists believe they are safe when they have donned their gloves and examine their patients behind a sheet of lead glass. But, unfortunately, these enable them only to avoid those superficial skin affections caused by the most absorbable rays of the spectrum.

“But they receive, alas, those other radiations which are more penetrating, and these slowly produce lesions of all the ductless glands in the body, whose internal secretions we now know to be of such vital importance in the bodily economy.”

The modern employment of 200,000 volts under three milliamperes gives rise to the need

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of great caution in the use of X-rays. Even the health of persons in adjoining rooms or buildings, Dr. Contremoulins believes may be imperiled. In the *Popular Science Monthly* for October, 1921, this veteran radiologist makes some startling revelations. To quote a few passages:

"In April, 1896, five months after the discovery of X-rays—or Roentgen rays, as they are also named in honor of their discoverer—a pose of eight hours was required for a correct radiograph of a profile head, the tube being placed ten inches from the sensitive plate.

"In April, 1921, a similar image was obtained in four hours at a distance of 90 yards from the apparatus. This means that the radiation with modern apparatus is more than 20,000 times stronger than was possible in 1896.

"With the very weak radiation that I have used for my experiments, corresponding to the ordinary radiographic and radiosopic work, it has been easy for me to obtain images of metallic objects and human bones placed on a sensitive plate 15 feet from the radiating source, although the rays pass directly through a slab of marble an inch thick, a sheet of lead one-tenth of an inch thick, and a flooring eight inches deep, built of oak boards and rough plaster.

"Fifty feet from this same source I have been able in four hours to fog a photographic plate placed behind a wall of brick and stone 20 inches thick. Also in the same time I have obtained a correct radiograph of a skull and a crab, 262 feet from the X-ray machine. All these experiments were made with a 17-centimeter spark and two milliamperes of current.

"If photographic plates are so readily affected by these rays, we must admit that animal cells also are affected to an appreciable degree. The X-rays that are being used to cure a patient may at the same time inflict radio-dermatitis on other persons exposed to their influence in adjoining rooms or buildings. Nothing will suffice for safety but to cover the walls and floors of X-ray rooms with sheets of lead from a quarter to half an inch thick, according to the power of the source and its distance from the lining. . . .

"Biologic reactions from X-rays take two forms. The first is a skin lesion known as radio-dermatitis, caused by the skin's absorbing a large quantity of radiations. The second results from the improvements in X-ray tubes and the use of filters absorbing the radiations of long wave length, currently named 'soft radiation.' This reaction takes place deep be-

neath the skin upon the active cells that are the most vulnerable. It is principally the internal secretion glands that are affected. Among those who continually receive even weak doses, a gradual lessening of vitality takes place, leading slowly to a physiological impoverishment that inevitably carries them off sooner or later."

Dr. Contremoulins was able to escape serious injury up to the outbreak of the World War, but is now a victim of his services to wounded soldiers. As a result of his efforts—and due also, partly, to suits brought against a Paris physician by neighbors who alleged that their health had been impaired, resulting (perhaps) in two cases of cancer—a thorough-going investigation was undertaken by the French Ministry of Hygiene.

Dr. Declere of the Academy of Medicine presided over a committee which included Mme. Curie, M. Becquerel, a radiologist; Dr. Vaillant and a number of specialists. A leading member of the Academy said he did not believe that X-rays menaced persons who did not come into direct contact with them.

"I intend to study the question by three methods," he said. "First, we shall make a purely physical examination, studying the ac-

tion of the rays and in what measure they exert themselves at certain distances. Second, we shall experiment with the living tissues of rabbits, trying various distances several hours a day and noting the effect on the red and white corpuscles and glands of the animals. Then, since it is impossible to make such experiments on human bodies, we shall collect data based on 25 years' experience with X-rays to see whether physicians in close contact have been burned."

While X-ray treatment cannot be said to *cure* a deep-seated cancer, it is undoubtedly being given with highly beneficial results in many cases, alleviating much suffering and retarding the growth of malignant tissues.

As is well known, tuberculosis can advance to a dangerous stage before it exhibits physical symptoms recognizable by physicians. The X-ray not only brings to light incipient consumption, but reveals the exact place and extent of the lesion. Any abnormalities of the alimentary tract, also, may readily be brought to view, as well as certain effects produced on certain arteries, due to arterio-sclerosis or to angina pectoris (a very painful form of heart disease).

It has been well said that "the list of dis-

eases, the presence and extent of which are betrayed or confirmed by the X-ray, would fill pages and would include most of the enemies to human health. Among them may be mentioned many forms of tuberculosis, occult abscesses whose ramifying consequences physicians were once unable to refer to their source, tumors, cancers, kidney stones, gastric ulcers, diseases of the heart."

The martyrdom of radiologists has not been in vain.

In cases of emergency, X-ray diagnosis may now be given patients in their own homes. A surgical X-ray outfit that can be carried in an ambulance and taken to the bedside of a patient too ill for removal to a hospital passed a successful trial in England, thus adapting an emergency war-time arrangement to civilian use. A generator in the ambulance operates the tube, which has a special mounting that enables it to be placed over the patient's bed, and adjusted for height and position by hand-wheels. The control apparatus is mounted on a separate stand, and connected with the ambulance outside by a cable wound on a reel. Provision is made for developing the exposed plates at once, so that a diagnosis can be made in a few minutes.

CHAPTER IV

DISCOVERY AND NATURE OF X-RAYS

In March, 1923, there passed from this world one of the most beautiful exemplars of the true scientific spirit that earth has ever seen—Dr. William Conrad Roentgen, F.R.S., Professor of Experimental Physics in the University of Munich, the discoverer of X- or Roentgen Rays.

Born at Lennep, on March 27, 1845, Professor Roentgen filled a number of important posts before his death in 1923, in which year he was awarded the Nobel Prize in Physics—an award which brought with it a gift of \$40,000. Although suffering from the poverty which resulted in Germany as an aftermath of the World War, Professor Roentgen refused to utilize the Nobel Prize award for his own personal uses. He gave the entire sum to a research society to enable other students to carry on their investigations.

While occupying the chair of Professor of Physics and Director of the Physical Institute at Würzburg, Dr. Roentgen made the discovery—in 1895—for which his name is chiefly known—though his researches led to important advances in several other departments of physics.

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While experimenting with a highly exhausted vacuum tube on the conductivity of electricity through gases, Dr. Roentgen noticed that a paper screen covered with potassium platinocyanide—a phosphorescent substance—which chanced to be lying nearby, became fluorescent under action of some radiation emitted from the tube, which at the time was enclosed in a box of black cardboard. Professor Roentgen then found, by experiment, that this heretofore unknown radiation had the power to pass through various substances which are impenetrable to ordinary light-rays. He found that if a thick piece of metal—a coin, for example,—were placed between the tube and a plate covered with the phosphorescent substances, a sharp shadow was cast upon the plate. On the other hand, thin plates of aluminum and pieces of wood cast only partial shadows.

Thus was it demonstrated that the rays which produced the phosphorescence on the glass of the vacuum tube could penetrate bodies quite opaque to ordinary light-rays. Like ordinary light, these rays affected a photographic plate; but owing to their peculiar behavior in regard to reflection and refraction, Roentgen was led to put forward the hypothesis that the rays were due to longitudinal, rather than to transverse waves in the “ether.” They

will ionize gases, but they cannot be reflected, polarized or deflected by a magnetic or electric field, as are ordinary light-rays. (It has been shown that the *scattered* secondary rays show polarization.)

Being in doubt as to the real nature of these penetrating rays, Roentgen called them "X-rays."

In 1896 Professor Roentgen was the recipient of the Rumford Medal of the Royal Society. This honor was shared by his compatriot Philipp Lenard. Lenard was the discoverer of the rays emanating from the outer surface of a plate composed of (any) material permeable by cathode rays. By impinging on solids, the cathode rays (negative electrons) generate X-rays. "Lenard rays," which are similar in all their known properties to cathode rays projected from the cathode of a vacuum tube, do not emanate from the cathode. (Unlike the X-rays, cathode rays may be deflected from their natural course along "straight lines" by the application of a magnetic or electric field.) Professor Lenard, as also Hertz, discoverer of the now well-known "wireless waves," had already demonstrated that a portion of the cathode rays could pass through a thin film of a metal such as aluminum.

When Roentgen rays (X-rays) are allowed to fall upon any substance, the matter emits cathodic (or secondary Roentgen) rays. "The characteristic secondary radiation may be compared with the phosphorescence produced by ultra-violet light, and the cathodic secondary rays with the photoelectric effect" (Sir J. J. Thomson).²

The penetrating power ("hardness") of these rays appears to be determined solely by the nature of the elements in the emitting substance. The velocity of the cathodic (or secondary Roentgen) rays seems to be quite independent of the matter exposed to the primary rays, but increases as the hardness (penetrating power) of the primary Roentgen rays increases.

The *character* of the emitted rays, in brief, appears to be quite unaffected by the chemical or physical condition of the element. Red-hot iron, for example, exhibits the same characteristic Roentgen radiation as iron at room tem-

²When ultra-violet light is allowed to fall upon a metal it causes the metal to emit electrons and thus to acquire a positive charge, the velocity of the emitted electrons being exactly proportional to the frequency of the incident light. Or when light of X-ray type falls upon the surface of almost any substance, it takes hold of an electron in the atoms of that surface and hurls it out into space with a speed exactly proportional to the wave length of the light. This phenomenon is known as the photoelectric effect.

perature. But the *penetrating power* (hardness) of this characteristic (emitting) radiation increases gradually and continuously with increasing atomic weight of the emitting elements. The complete independence of the penetrating power of the characteristic Roentgen radiation from external surroundings indicates strongly that it is closely connected with the nature of the nuclei ("cores") of the atoms giving rise to it.

CHAPTER V

ULTRA-VIOLET LIGHT IN HEALTH AND DISEASE

That both the compound rays of ordinary sunlight and ultra-violet rays ("artificial sunlight") are highly effective in the treatment of a number of complaints is now well known. They are both in general use for the external treatment of rickets, tuberculosis, and a number of other diseases. Light-rays are also applied to hasten the healing of wounds.

The use of the sun as a healing agent seems first to have been developed in a scientific way by Dr. Neils R. Finsen, a young Danish physician who was later awarded the Nobel Prize in Medicine. His original researches were undertaken toward the end of the 19th century. Then Dr. Rollier opened the first sunlight clinic in 1903, and in 1910 established his school at Leysin, in the Alps. Dr. Rollier is now treating about 1,000 patients, mostly afflicted with various forms of tuberculosis of the bone. The sun cure is also used to some extent for pulmonary tuberculosis, and with considerable success. (See my *Man's Debt to the Sun*, Little Blue Book No. 808, Chapter IV.)

According to Dr. Rollier, exposure of the diseased to the sun's rays is efficacious in the treatment of anemia, malnutrition, bone and gland infections and various types of tuberculosis, and is a body builder for convalescents. On the outskirts of San Rafael, California, is a novel sun sanitarium, Helios Sanitarium, modeled after the Alpine sanitarium of Dr. Rollier.

Two investigators have recently studied the comparative germ-destroying power of the blood in healthy and ill persons, before and after exposure to sunlight. It was found that the germ-killing power of the blood was increased when the sun bath lasted for a certain length of time. It was shown that too long or too short an exposure decreased the blood's power. It was decreased also in patients who had fever. Several other conditions were found to influence the results. Physicians believe that several points of practical value may emerge from these experiments. One important and useful result is that they offer a new method to guide and gauge the effects of treatment in tuberculosis and other diseases.

The practice of X-ray treatment (since 1910 included under the more general term *radiotherapy*) includes treatment not only by X-rays, but also by all kinds of rays—treatment by heat, by the sun's rays, by ultra-violet rays, and

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even by violet rays. The rays of radioactive substances used in medicine come under the etymological term of radiotherapy. But in general practice, amongst radiologists, the term is applied to treatment by X-rays alone. Nevertheless, it is now well established that the ultra-violet rays are not only bactericidal, but that they also play an important role in the treatment of certain diseases, and in the maintenance of good health. On the other hand, these rays produce a certain irritability among persons of the white race in the tropics, which cannot be regarded as healthful in their general effects.

Since the amount of ultra-violet light coming from the sun has been shown by Abbott to be variable, it may be that some of the irritability which seems to be general among the inmates of our public institutions on certain days is due to this change in the sun's outpour of ultra-violet radiation. As Dr. E. E. Free remarked not long ago:

"Put these facts together. Ultra-violet rays affect life. The amount of ultra-violet coming from the sun is variable. Does this mean that some of the obscure, day by day variations of health can be due to this? Some days everybody seems happy and cheerful. Other days everybody is depressed. Still other days are

breeders of 'nerves.' Maybe the ultra-violet does it. Maybe not. Doubtless the investigators will find out presently."

Recent experiments at the Maine Agricultural Experiment Station, conducted under the direction of Dr. John W. Gowen, have led to the important discovery that milk from cows that have been treated with ultra-violet light, from mercury-vapor quartz lamps, contains a much larger amount of the substance—presumably a vitamine, or vitamines—that prevents rickets in children and young animals. At any rate, it was found that the milk from cows deprived of sunlight and ultra-violet light was quite deficient in the anti-rachitic factor. Animals and birds fed on the sunless milk uniformly developed rickets.

The Holstein-Friesian cows used in the experiments were of nearly the same age and calving date and all received like treatment as to feed, temperature, etc., and stood side by side in the same barn. "Throughout the treatment," says Dr. Gowen, "these cows did not leave the barn. For one month none of the cows received ultra-violet light. For the second month two cows received ultra-violet light 15 minutes a day, generated from a Cooper-Hewitt alternating current light at three feet above their backs. For the third month these cows

received ultra-violet light for 30 minutes a day under the same conditions. In the meantime Rhode Island Red chickens were allowed to develop rickets, shown both clinically and by X-ray photographs. They were divided into two lots, one lot of these chickens receiving milk from the ultra-violet cows, the other of two lots of chickens, milk from the control cows. Both lots received all the milk they wished.

The chickens have now been under treatment 50 days. The lot receiving milk from cows exposed to ultra-violet light are in good condition with no appearance of rickets in X-ray plates. The lot receiving normal milk has moved progressively toward more extreme clinical and X-ray rickets. The experiment was repeated, using the milk from these same cows on White Leghorn chickens showing clinical and X-ray rickets. Five chickens were in each lot. After 38 days' treatment four of the lot receiving milk from the ultra-violet cows are almost cured of rickets, showing only a very slight stiffness. The fifth chicken shows some stiffness. Four of the lot receiving the normal milk show constantly increasing symptoms of the more advanced stages of clinical rickets.

These results point to the conclusion that more of the substance necessary to cure rickets is absorbed by the cow exposed to ultra-violet light and secreted by her in her milk. The cows prevented from receiving ultra-violet light are not able to secrete this anti-rachitic substance in sufficient quantities to cure or allay the process of clinical rickets. The results thus point to an environmental factor transmitted by the cow to her offspring through the medium of her milk. They further suggest that the high incidence of rickets in children during the late winter months is due to their mothers not receiving ultra-violet light either during pregnancy or while in lactation. Furthermore, it would appear that cow's milk produced especially for

baby-feeding should be from cows which have access to ultra-violet light either from the sun or from some other source.

Dr. C. C. Little of the University of Maine, and his associates, fully demonstrated the value of sunlight to animal life through experiments on a flock of 233 chicks. The chicks were divided into three groups and all were given the same diet. One group was kept in natural sunlight, the second was kept in sunlight that went through window glass, and the third was given both natural sunlight and extra ultra-violet rays produced artificially. The last class grew the best. The class that got only natural sunlight grew normally. The class kept behind window glass all developed bone disease. The glass of the greenhouse allowed the light of the sun and the heat of infra-red rays to get through. But it screened out the ultra-violet waves.

The beneficent effects of invisible ultra-violet rays are seen in both the organism exposed to them and the food consumed. This is true whether the rays come direct from the sun or by means of a quartz lamp. Ordinary glass lamps prevent the ultra-violet rays from passing out. But not all kinds of foodstuffs by any means are favorably affected by the rays. Only those foods which contain fat seem to be

materially improved. The value of milk and of cod liver oil is greatly enhanced by exposure to the rays. Dr. Benjamin Kramer has been highly successful in treating babies affected with rickets by subjecting milk itself to the action of ultra-violet light.³

As early as 1923, it had been shown by feeding experiments with various types of animals at the University of Wisconsin that sunlight was acting either directly upon the animal or upon its food. The same dietary was found to produce contradictory results. It was established—especially by H. Steenbock and E. B. Hart—that sunlight is indispensable to man and beast, in that it is the determinant of the efficiency with which calcium can be assimilated and retained. (See their report, *Journal of Biological Chemistry*, Vol. 62, page 577, 1925.) Calcium, it is pointed out, needs to be conserved because in proportion to the body needs it is not found abundantly in foods and feeds. Steenbock and Hart tell us that sunlight plays the particular rôle of conservator “by virtue of its content of ultra-violet radiations of approxi-

³It is interesting to note in this connection that Kuzelmass and McQuarrie have suggested that oxidation of cod liver oil gives rise to ultra-violet radiation. (See *Science*, September 19, 1924.)

mately 250 to 302 millimicrons in wave-length, but unfortunately these are not present in sufficient degree to provide a wide margin of safety for the animal. As a result we have rickets in the young and poor dentition, restricted lactation, abortion and impoverishment of the skeleton in lime to a dangerous extent in the adult. . . . The ultra-violet rays bring their effect through the medium of certain compounds widely distributed in plant and animal tissue, so that practically any foodstuff can be 'anti-rachitically' activated. 'Make hay while the sun shines' is more than a mere poetic slogan, for hay made in the dark is devoid of rickets-preventing properties" (*Science*, December 4, 1925).

The careful experiments of J. S. Hughes showed that chickens receiving a standard scratch feed and mash, supplemented with sprouted oats and buttermilk, developed rickets (weak legs) when deprived of direct sunlight. Chicks receiving the same feed but given sun baths developed normally, although they were confined in a very small pen, with little opportunity to exercise. Light from ordinary electric bulbs had very little, if any, beneficial action. Light from the Hereus mercury arc lamp was very beneficial. Cod liver

oil also proved to be effective in preventing rickets in chickens as in mammals.⁴

That such fats as olive oil and lard may be activated by exposure to ultra-violet rays and used as a substitute for cod liver oil in the treatment of rickets is evidenced by experiments reported by the Department of Agricultural Chemistry of the University of Wisconsin. In the series of experiments now published, olive oil and lard were exposed to the action of the ultra-violet rays from a powerful mercury-vapor quartz lamp, for periods of time ranging from half an hour to 17 hours.

After exposure to the rays these fats were fed to a group of experimental rats in which rickets had been produced, and the activated olive oil and lard were found to have the same beneficial results that follow the administration of cod liver oil. The weight of the rats increased and an analysis of the bones showed an increase in the calcium content.

Some of the activated olive oil, which had been stored in a stoppered bottle, showed no change in potency ten months later. It was found also that the fats might be activated by the rays from the open carbon arc, the iron

⁴Paper read before the 66th meeting of the American Chemical Society, held in Milwaukee, Wis., September 10th to 14th, 1923.

arc, and sunlight; but that exposure for such prolonged periods as 17 hours destroyed their potency. This destruction took place even on cod liver oil.⁵

It has long been known that human tissue is more actively changed by light when it has been "sensitized." Quinine, esculin, fluoresceine, etc., are examples of tissue sensitizers, in addition to their other effects. The most powerful of all known sensitizers is haemoporphyrin—or simply "porphyrin." This sensitizer is a purple substance closely allied to the haemoglobin that gives blood its red color. Subtracting its iron and albumin from haemoglobin by appropriate chemical processes leaves porphyrin. This substance reacts strongly to the ultra-violet rays, in rare cases causing a disease which turns the teeth to a deep purple hue. Victims of this uncommon ailment have to wear gloves constantly, and when going out of doors during the day time must put on

⁵Dr. Harriette Chick and her co-workers of the Vienna University Child Clinic discovered, first, that the action of cod liver oil on the bone-lesions of rickets has an exact parallel in that of the ultra-violet rays of sunlight, or of the rays from a mercury-vapor quartz lamp; and, second, that the oil and the rays were effective substitutes the one for the other. See my *Man's Debt to the Sun*, Little Blue Book No. 808, page 49.

heavy veils.⁶ Porphyrin is capable of dissolving the red corpuscles of the most dissimilar animals in the presence of sunlight. But neither the haemato-porphyrin nor the light alone is capable of injuring the animals. Only the combined effect of the two can harm them. A physician experimentally injected an exceedingly minute quantity into himself and then exposed himself to a moderate light, and became very ill.

Hausmann found that even the diffused sunlight of an early spring day in Vienna was sufficient to cause the death of white mice which had been subjected to small quantities of this strange substance. Dr. E. C. Van Leersum, of Holland, proved by experiments with rats that the utilization of lime by our bodies can be controlled almost at will by this "sen-

⁶The only creature that has porphyrin as part of its normal body-covering is a tropical bird called the touraco, parts of whose feathers are dyed a brilliant red by a porphyrin-copper compound known as turacin. This pigment is remarkable also because it seems to be the only normal occurrence of copper as a coloring compound in feathers or skin. Turacin is soluble in weak alkali, so that when it rains and the bird comes into contact with such alkaline solutes as frequently occur in nature, the turacin bleaches out! Although porphyrin is rare as a normal coloring in adult animals, it is the commonest pigment found in the shells of birds' eggs. Almost all eggs, from the hen's brown to the robin's blue, contain it.

sitization" process. Rickets, or a condition indistinguishable from rickets, can be produced or cured by proper control of the sensitization.

SUNLIGHT AND INFANTILE PARALYSIS

An article by Science Service, quoted in *Science*, September 11, 1925, says:

Another of the dreaded diseases of childhood, infantile paralysis, which, like rickets, graduates large quotas of cripples, has responded to the good influence of the sun's rays. Dr. G. Murray Levick, medical director of the Heritage Craft Schools at Chailey, Sussex (England), who originated the treatment, said that no other method has ever had as good results as this in the treatment of infantile paralysis.

Dr. Levick first deduced that neurasthenia in grown-ups and rickets in the young are due to the same cause. Both these diseases, he claims, are nutritional disturbances of the nerve centers affecting the bones in the young, and the nervous systems in the old. The action of sunlight on the skin forms a substance which is carried into the blood and feeds the nerve centers as well as the bones. His success in treating neurasthenia with sun's rays led him to apply it to cases of infantile paralysis, a disease which is a severe shock to the nervous system and which results in muscular atrophy. Under the action of sunlight a renutrition of nerve centers takes place.

Synthetic sunlight produced by him with an electric arc light of his own invention proved as good as natural sunlight, and could be better regulated to the patient's endurance. He used two distinct kinds of light-rays, the short ultra-violet rays for nerve nutrition, and the long red and infra-red rays for muscle treatment. Red rays, as can be seen when the hand is held up against the sunlight, penetrate the flesh to a considerable extent, and can therefore stimulate the sleeping muscle.

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Dr. Levick warns that immediate success must not be expected. He has found constant improvement where short daily treatments were continued over a period of several years. While the method may not be effective in extreme cases, it is nevertheless a test which will soon show after a few treatments whether any rejuvenation of the nerve fiber is taking place.

It is now admitted that the (red) heat-waves may play some part in heliotherapy—exposure to direct sunlight for medical purposes. Dr. Lazarus-Barlow, Professor of Experimental Pathology in the University of London, concludes that even though heat-rays may also play some part in curative processes, “experience of the treatment of wounds by sunlight in France during the World War indicated that a degree of benefit arises from exposure to sunlight which cannot be attributable to warmth and ultra-violet rays. On the other hand, in the Finsen light treatment of lupus (a tubercular affection of the skin of the face, occurring in several forms) and in the treatment of tuberculosis at high altitudes, ultra-violet rays play a predominant part.”

As the ultra-violet rays penetrate but a fraction of a millimeter into the epithelium, “it is uncertain how the rays act.” The suggestion is here ventured that since the recently discovered Millikan Rays are particularly powerful under the same conditions that make ap-

plication of the ultra-violet rays practicable as a therapeutic agency, it may later be found that these highly penetrating rays, of exceedingly short wave length, aid greatly in effecting some of the cures now attributed wholly to the longer (and less penetrating) ultra-violet rays or the much shorter X-rays.⁷

Professor Lazarus-Barlow calls attention to the fact that it is precisely those tubercular persons who tan easily who are said to derive the greatest benefit from a sojourn at high altitude.

Very remarkable is a recently adopted machine which "pours ultra-violet light through a funnel down the throat of a patient." The new apparatus, first used in London, is employed for treatment of various mouth and throat diseases, "thus making it possible for patients to take internal baths of artificial sunlight" (*Science*, February 26, 1926).

In England, where the sky is so often overclouded, it is natural that much attention has been given to ultra-violet ray therapy. A recent press dispatch tells us:

"London recently had 23 consecutive days on

⁷The length of the very short X-rays was accurately determined by a new method developed by Compton and Doan in 1925, and was found to be about three billionths of an inch.

which no beam of the sun could force its way through the mantle of cloud and fog which spread over that section of England. Now the Britons are making artificial suns that may be available for both indoor and outdoor illumination. Arc lights throwing powerful ultra-violet rays are being installed in beauty shops and hotels, and patrons are given opportunity to bathe their bodies in this brilliance. These rays are being billed as more potent than sun baths, and citizens who have small chance to see the orb of day get their sunshine and their medicine at one swoop."

Two Indian scientists, S. S. Bhatnagar and R. B. Lal, of the University of the Punjab, Lahore, discovered in 1925 that germs grow faster when exposed to "polarized" light than to ordinary light. (Ordinary light—according to the undulatory theory—is due to vibrations transverse to the direction of the ray, but varying so rapidly as to show no particular direction of their own, the fronts of the light-waves crisscrossing at all angles. When, by any means, these vibrations are given a definite direction, the light is said to be *polarized*, the fronts of the waves being all arranged in the same direction, though the path of the rays may be plane, elliptical, circular, or rotary, according to the method of polarization employed.)

The Indian experimenters took cultures of the germs of typhoid fever and cholera, and

exposed one set to ordinary light, and another to a beam of polarized light. The latter multiplied much faster than did the germs under ordinary light.

It was demonstrated in 1925 by Dr. Elizabeth S. Semmens, of Bedford College, London, that the digestion of starch takes place more readily under polarized light than in ordinary light.

Prolonged exposure to the ultra-violet rays will destroy any germs known to science. (Cathode rays—which are shorter than ultra-violet rays—will kill not only germs, but insects as well, by means of a device developed by Prof. W. D. Coolidge.)

“Bacteria,” says Dr. Coolidge, “have been rayed, and an exposure of a tenth of a second has been found sufficient to kill even highly resistant bacterial spores. Fruit flies, upon being rayed for a small fraction of a second, instantly showed almost complete collapse, and in a few hours were dead.”

This may lead to the application of cathode rays as a germicide, but their effect on higher forms of life shows that their unskilled use would be most dangerous. For example, Dr. Coolidge relates:

“The ear of a rabbit was rayed over a circular area one centimeter in diameter for one second. After several days a scab formed which fell off a few days later, taking the hair with it. Two weeks later a profuse growth of snow-white hair started which soon became much longer than the original gray hair. Another area was rayed for 50 seconds. In this

case, scabs developed on both sides of the ear, which scabs later fell out, leaving a hole. The edge of this hole is now covered with snow-white hair."

A very interesting problem to scientists relates to the question as to whether or not insects are color-blind. It may be that we now have at least a partial answer to this vexed question, and in terms of ultra-violet radiations.

Dr. Frank E. E. Germann, of Cornell University, calls attention to some recent experiments which show conclusively that at least one kind of insects (flies) have a range of vision in the ultra-violet, just as we have in the visible spectrum. It was also made "perfectly evident that flowers do have their characteristic ultra-violet radiations" (*Science*, March 26, 1926, page 325). It is due "to our own egotism that we call the insect color-blind."

A given type of insect might in reality be visiting flowers of the same color as far as it was concerned, while to us it appeared to be visiting flowers of all colors. "Might not two flowers, one red and one blue, both give out the same group of wave lengths in the ultra-violet, and thus be identical in color to an insect seeing only the ultra-violet? Moreover, what is to prevent two different kinds of red flowers from giving out two entirely different sets of wave lengths in the ultra-violet, and thus appearing to have entirely different colors to an insect?"

In a very real sense, science is only at the beginning of the discoveries it will yet make in its investigations of the nature and action of ultra-violet, cathode and X-rays.

